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Method and installation for enriching a gas stream with one of the components thereof

The present invention relates to a method and to an installation for enriching a gas stream with one of its constituents. In particular, it relates to a method of enriching air with oxygen.

The oxygen enrichment of air has become necessary in the iron and steel industry.

The reduction or elimination of hot coke in blast furnaces, generally to the benefit of coal powder injection (CPI), requires this necessary change.

The means known from EP-A-0 531 182 for economically achieving this enrichment consists in cryogenically distilling one portion of the stream of air for the blast furnace. What is thus obtained is a nitrogen-rich stream and an oxygen-rich stream, the latter then being remixed into the stream of air downstream of the air separation unit.

Since the pressure of the oxygen stream is close to that of the air stream feeding the air separation unit (ASU), a method involving a mixing column will prove to be particularly suitable and economic.

Figure 1 shows a separation unit described in EP-A-0 531 182 intended for enriching air with oxygen. It is fed from the air system constituting the charge for a blast furnace at a pressure P. The air distillation unit is intended to produce low-purity oxygen, for example having a purity of 80 to 97% and preferably 85 to 95%, at a defined pressure slightly above the pressure P, for example advantageously at a pressure of 1×10^4 Pa abs to 1×10^5 Pa above the pressure P.

The unit essentially comprises a heat exchange line 1A, a double distillation column 2A, which itself comprises a medium-pressure column 3A, a low-pressure column 4A and a main condenser-reboiler 5A, and a mixing column 6A. The columns 3A and 4A typically operate at about 5.45×10^5 Pa and about 1.5×10^5 Pa respectively.

As explained in detail in document US-A-4 022 030, a mixing column is a column having the same structure as a distillation column but used for mixing in a manner close to reversibility, a relatively volatile gas, introduced at the bottom of the column, with a less-volatile liquid, introduced at the top of the column.

Such mixing generates refrigeration energy and therefore allows the energy consumption associated with the distillation to be reduced. In the present case, this mixing is also profitably used for impure oxygen to be produced directly at the pressure P, as will be described below.

In the case of figure 1, an airstream is compressed to the pressure of the mixing column by a compressor 14A, cooled in the exchange line 1A, subcooled in the subcooler 21A and sent to the bottom of the mixing column 6A.

"Rich liquid" (oxygen-enriched air), withdrawn from the bottom of the column 3A, is, after being expanded in an expansion valve 10A, introduced into the column 4A. "Lean liquid" (impure nitrogen) withdrawn from an intermediate point 11A on the column 3A is, after being expanded in an expansion valve 12A, introduced into the top of the column 4A, constituting the waste gas of the installation, which gas and the pure gaseous nitrogen at medium-pressure possibly produced at the top of the column 3A are warmed in the exchange line 1A and

discharged from the installation. These gases are indicated by NI and NG in figure 1, respectively.

Liquid oxygen, of greater or lesser purity depending on the setting of the double column 2A, is withdrawn from the bottom of column 4A, raised by a pump 13A to a pressure P1, slightly above the aforementioned pressure P, in order to take account of the pressure drops (P1-P less than 2×10^5 Pa), and introduced into the top of the column 6.

Three fluid streams are withdrawn from the mixing column 6A: from its base, liquid similar to the rich liquid and joined with the latter via a line 15A provided with an expansion valve 15A'; from an intermediate point, a mixture essentially consisting of oxygen and nitrogen, which is sent to an intermediate point on the low-pressure column 4A via a line 16A provided with an expansion valve 17A; and, from its top, impure oxygen which, after being warmed in the heat exchange line, is discharged, substantially at the pressure P, from the installation via a line 18A as production gas OI.

The figure also shows auxiliary heat exchangers 19A, 20A, 21A for recovering available refrigeration from the fluids circulating in the installation.

Figure 2 shows schematically an integrated apparatus for enriching an airstream intended for a blast furnace according to the prior art.

An airstream is compressed in a blower S, so as to form a compressed stream 1. This stream is divided into two fractions 2 and 3. The first fraction 2 is cooled by a chiller R, for example a water chiller, compressed in a booster C and sent to an air separation unit (ASU). The air separation unit operates for example by cryogenic distillation and includes, upstream of the separation

columns, a purification unit and an exchange line. It produces a stream 10 of oxygen containing between 80 and 95 mol% oxygen and a nitrogen stream 11, which may be a waste stream. At least one portion of the oxygen-enriched stream 10 is mixed with the second air fraction 3. The oxygen-enriched, mixed stream 15 is heated in a cowpers W and sent to a blast furnace BF.

To counteract the pressure drops in the circuit comprising the air separation unit (between the air intake on the blast furnace wind to the separation unit and reinjection of the oxygen stream), a compressor C will be installed. This makes it possible to raise the pressure of the total airstream intended for the air separation unit (according to figure 2) or (as a variant of figure 1) of the airstream intended for feeding the mixing column (i.e. about 30% of the stream of air treated by the separation unit).

It is an object of the invention to integrate an air separation unit into this steelmaking process in a more economic and more reliable manner, without the use of any gas stream compressors in the air separation unit other than those connected to the shaft of the expansion turbine for maintaining the refrigeration of the separation unit.

One subject of the invention is a method of enriching a pressurized gas stream with one of its constituents A, which comprises the steps of:

i) dividing the stream into at least first and second fractions;

ii) sending at least one portion of the first fraction into a separation unit;

iii) supplying, from the separation unit, at least first and second streams, the first stream of which has a content of constituent A greater than that of the first fraction;

iv) mixing at least one portion of the first stream with at least one portion of the second fraction in order to form a pressurized gas mixture,
characterized in that the second fraction is expanded before at least one portion of the first stream is mixed therewith.

According to other optional aspects:

- the pressurized gas stream and the first fraction are substantially at the same pressure and, in particular, only the pressure drops are the cause of a variation in pressure between these two fluids;

- the first stream and the expanded second fraction are substantially at the same pressure and, in particular, only the pressure drops are the cause of a variation in pressure between these two fluids;

- the separation unit is autonomous in terms of energy requirements for compressing the gas streams produced by the unit or intended for the unit;

- the pressurized gas stream is air and optionally constituent A is oxygen;

- the pressurized gas stream is air intended for a blast furnace;

- the separation unit is a cryogenic distillation separation unit;

- the separation unit comprises a medium-pressure column, a low-pressure column thermally coupled to the medium-pressure column, and a mixing column; and

- no portion of the first fraction intended for a distillation column is compressed or no portion of the first fraction intended for the mixing column or for the medium-pressure column is compressed after the stream is divided.

According to one particular method of operation i)in a first operation, at least one portion of the first fraction is compressed and the second fraction is not expanded before at least one portion of the first stream is mixed therewith; and

ii) in a second operation, (for example when the compressor C isn't working) at least one portion of the first fraction is not compressed (the first fraction is not compressed) and the second fraction is expanded before at least one portion of the first stream is mixed therewith.

Another subject of the invention is an installation for enriching a pressurized gas stream with one of its constituents A, which comprises:

i) means for dividing the pressurized gas stream into at least first and second fractions;

ii) a separation unit;

iii) means for sending at least one portion of the first fraction to the separation unit; and

iv) means for mixing at least one portion of a first stream, produced by the separation unit and enriched in A compared to the first fraction, with the second fraction in order to form a stream enriched in A compared to the pressurized gas stream,

characterized in that it includes a means for expanding the second fraction upstream of the means for mixing at least one portion of the first stream therewith, and downstream of the means for dividing the gas stream.

According to other optional aspects:

- the separation unit is an air separation unit comprising a medium-pressure column, a low-pressure column thermally coupled to the medium-pressure column, and a mixing column;

- the installation does not include any means for compressing air intended for the medium-pressure column or for the mixing column; and

- the installation includes means for compressing the second fraction and means for forwarding the second fraction to be mixed with at least one portion of the first stream without passing via the expansion means.

Advantageously, the separation method will use a mixing column operating at a pressure equal to or higher than the pressure of the medium-pressure column, without the need for an additional air compression means.

It is thus proposed to integrate a mixing-column unit into a blast furnace blaster without an additional air compressor, therefore increasing the reliability of delivery of oxygen molecules and therefore of enriched air to the blast furnace, while minimizing the investment needed for this construction.

Another subject of the invention is a method of separating air using an apparatus comprising at least one medium-pressure column, a low-pressure column thermally coupled to the low-medium-pressure column, and a mixing column operating at a pressure above the pressure of the medium-pressure column, in which:

i) air, compressed and purified, is sent to the medium-pressure column;

ii) nitrogen-enriched and oxygen-enriched streams are sent from the medium-pressure column to the low-pressure column;

iii) an oxygen-enriched liquid is sent from the low-pressure column to the top of the mixing column; and

iv) an oxygen-enriched gas is withdrawn from the top of the mixing column,

characterized in that a nitrogen-enriched liquid stream is withdrawn from the medium-pressure column, pressurized and at least partly vaporized, and the bottom of the mixing column is fed with at least one portion of the vaporized liquid.

Preferably, the nitrogen-enriched liquid is vaporized by heat exchange with part of the feed air. The air thus liquefied may be sent to at least one of the medium-pressure and low-pressure columns.

The nitrogen-enriched liquid is pressurized by a pump and/or by hydrostatic pressure.

Another subject of the invention is an air separation installation comprising:

a) a medium-pressure column;

b) a low-pressure column thermally coupled to the low-medium-pressure column;

c) a mixing column operating at a pressure above the pressure of the medium-pressure column;

d) means for sending compressed purified air to the medium-pressure column;

e) means for sending nitrogen-enriched and oxygen-enriched streams from the medium-pressure column to the low-pressure column;

f) means for sending an oxygen-enriched liquid from the low-pressure column to the top of the mixing column; and

g) means for withdrawing an oxygen-enriched gas from the top of the mixing column,

characterized in that it includes means for withdrawing a nitrogen-enriched liquid stream from the medium-pressure column, means for pressurizing the liquid, means for at least partly vaporizing the liquid and means for feeding the bottom of the mixing column with at least one portion of the vaporized liquid.

The invention will be described in greater detail with reference to figures 3, 4 and 5. Figures 3 and 5 show a unit for enriching a gas stream according to the invention and figure 4 shows a particularly suitable separation unit for carrying out the invention.

Figure 3 shows schematically an integrated unit for the enrichment of an airstream intended for a blast furnace according to the prior art.

A stream of air is compressed in a blower S in order to form a compressed stream 1. This stream is divided into

two fractions 2 and 3. The first fraction 2 is cooled by means of a chiller R, for example a water chiller, and sent to an air separation unit (ASU) without being compressed between the chiller and the inlet of the air separation unit. The air separation unit operates for example by cryogenic distillation and includes a purification unit and an exchange line upstream of the separation columns. It produces an oxygen stream 10 containing between 80 and 95 mol% oxygen and a nitrogen stream 11, which may be a waste stream. The second air fraction 3 is expanded by means of an expansion means V, which may for example be a valve, an orifice, a reduced-diameter pipe or a turbine. At least one portion of the oxygen-enriched stream 10 is mixed, downstream of the expansion means V, with the expanded second air fraction 3. The oxygen-enriched, mixed stream 15 is heated in a cowpers W and sent to a blast furnace BF.

This solution dispenses with the air booster for raising the pressure upstream of the air separation unit. The consumption of energy of the whole system will therefore be better.

Figure 4 adopts elements of figure 1 having the same reference numerals, which will not be described in detail.

The purified air 7a at the medium pressure of 5.45 bara coming from the main air compressor for the blast furnace wind or from an expansion turbine is separated into at least two separate flows before entering the medium-pressure column 2A.

The first flow 100 is fed directly into the bottom of the medium-pressure column 2A in gaseous form.

The second flow 200 is at least partly condensed in a heat exchanger 101A. The liquefied portion is

introduced into one of the distillation columns (either the medium-pressure column 2A or the low-pressure column 4A). In figure 4, the stream 202 is sent to the bottom of the medium-pressure column, whereas the stream 204 is sent to the low-pressure column after being subcooled in the exchanger 19A.

A liquid stream 300 enriched in nitrogen compared to air is withdrawn from the medium-pressure column 3A, compressed by means of a pump 400 or by a simple hydrostatic height, vaporized in the heat exchanger 101A against the condensation of medium-pressure air, in order to form a gaseous nitrogen stream 500 which is then fed into the bottom of the mixing column 6A. Thus, profiting from the difference in composition between the air and the nitrogen-enriched stream, the feed for the mixing column 6A takes place at a pressure above that of the air 100 feeding the medium-pressure column 3A, and does so without an additional compressor.

It is also conceivable to warm the gaseous nitrogen 500 in the main exchange line before introducing it into the mixing column.

To produce a gaseous nitrogen stream 500 at 5.9 bara, the heat exchanger 101A has a ΔT of 0.6°C.

The stream 15A coming from the bottom of the mixing column 6A, being richer in nitrogen than that of figure 1, is sent to just below the top of the low-pressure column 4A.

The subcooler 21A is omitted and there is no longer any withdrawal of medium-pressure gaseous nitrogen NG.

Optionally, a third flow of air is sent to a booster 8A, cooled in the exchange line 1A and expanded in the blowing turbine 9A, but other means of refrigeration

are conceivable, including expansion of the air intended for the medium-pressure column.

If this booster is present, the advantage of the invention is that there is no need for an air compression step for air intended for the mixing column or for the medium-pressure column.

In the case of figure 4, the extraction efficiency is reduced and the separation energy of the system remains superior to the base case.

However, integrating the air separation unit of figure 4 into the scheme disclosed in the variant shown in figure 3 does allow the pressure drop in the valve to be considerably reduced.

Figure 5 shows schematically an integrated unit for enriching a stream of air intended for a blast furnace according to the prior art.

A stream of air is compressed in a blower S in order to form a compressed stream 1. This stream is divided into two fractions 2 and 3. The first fraction 2 is cooled by means of a chiller R, for example a water chiller, compressed in a booster C and sent to an air separation unit (ASU). The air separation unit operates for example by cryogenic distillation and includes a purification unit and an exchange line upstream of the separation columns. It produces an oxygen stream 10 containing between 80 and 95 mol% oxygen and a nitrogen stream 11, which may be a waste stream. The second air fraction 3 is expanded by means of an expansion means V, which may for example be a valve, an orifice, a reduced-diameter pipe or a turbine. At least one portion of the oxygen-enriched stream 10 is mixed, downstream of the expansion means V, with the expanded second air fraction 3. The oxygen-enriched, mixed stream 15 is heated in a cowpers W and sent to a blast

furnace BF. The booster C and the valve V have short-circuiting means. In a first operation of the unit, the first fraction 2 is compressed and the second fraction is not expanded. In a second operation, at least one portion of the first fraction is not compressed and the second fraction is expanded before at least one portion of the first stream is mixed therewith.

Evaluation of the variants:

PRIOR ART

		BLOWER	Air sent to the ASU	O_2 at the BF		Enriched air at the BF
FLOW RATE	Sm^3/h	400 000	146 700	3 748	95% O_2 eff.	284 048
Composition	N_2	0.7811	0.7811	0.03		0.700
	O_2	0.2096	0.2096	0.95		0.290
	Ar	0.0093	0.0093	0.02		0.010
		1	1	1		1
PRESSURE	bara	5.85	5.55	5.50		5.50
ENERGY	kW	30 686	1201			31 887

VARIANT 1 with an expansion valve (figure 3)

		BLOWER	Air sent to the AsU	O_2 at the BF		Enriched air at the BF
FLOW RATE	Sm^3/h	400 000	146 700	30 748	95% O_2	284 048
		0	0	0	eff.	0
Composition	N_2	0.7811	0.7811	0.03		0.700
	O_2	0.2096	0.2096	0.95		0.290
	Ar	0.0093	0.0093	0.02		0.010
		1	1	1		1
PRESSURE	bara	6.85	6.55	5.50		5.50
ENERGY	kW	33 428				33 428

VARIANT 2 with expansion valve (figure 3) and air separation method of figure 4

		BLOWER	Air sent to the ASU	O_2 at the BF		Enriched air at the BF
FLOW RATE	Sm^3/h	417 259	163 959	30 748.32	85% O_2 eff.	284 048
Composition	N_2	0.7811	0.7811	0.03		0.700
	O_2	0.2096	0.2096	0.95		0.290
	Ar	0.0093	0.0093	0.02		0.010
		1	1	1		1
PRESSURE	bara	6.23	5.93	5.50		
ENERGY	kW	33 151				33 151

	Prior art	VARIANT 1	VARIANT 2	REF. CASE
				Air blower intended for the mixing column
Overall cost	100	89	96	95
kW	100	105	104	90